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Professor Cayley, F.R.S., President, in the Chair

John Tebbutt, Esq., Windsor, N.S. Wales,
George Forbes, Esq., Anderson University, Glasgow,
Charles Carpmael, Esq., St. John's College, Cambridge,
W. S. Macdonnell, Esq., Sydney, N.S. Wales; and
Edwin Lawrence, 94 Westbourne Terrace,

were balloted for and duly elected Fellows of the Society.

A Proposed Double Altazimuth.

By R. C. Carrington, F.R.S.

It must have occurred to many members of the Royal Astronomical Society to ask themselves the question,—What is likely to be the next movement ahead in the construction of a first-class meridional instrument? I propose to suggest one such solution, with the view of possibly drawing out a criticism and discussing the primary principles which are to be kept to; and I do so without consideration of the cost, except that of two kinds of instrument the most efficient one shall have the choice. English artists have so long been the foremost constructors of such instruments that I should be sorry to see them surpassed by the Americans, French, Germans, or Russians. In the last generation seconds of arc were the battle-field of astronomers; now tenths of seconds have taken their place, shortly we may look for hundredths and thousandths.

My proposal is for a *Double Altazimuth*, capable of reversion in all its parts, with a perfectly open mirror or object-glass, without tube, and with reversible and exchangeable eyepieces, each carrying a setting circle of 2 feet diameter, and each floating hori-

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zontally. For the Equatoreal has one main defect, the contraction of the support of the polar end of the axis in excess of the lower end as temperature decreases, a defect which is common to all constructed at Konigsberg, Poulkova, Harvard, U.S., Greenwich, and elsewhere.

> 'Consider first, that great
> Or bright infers not excellence.'—MILTON.

It will be well to begin by referring to fig. 1, in which I have drawn a parabola on a large scale. I take the following proportions:—O F is 100 feet; consequently the points A and B are each 100 feet from F the focus. The tangents O A and O B, as is well known, intersect each other, at O, at right angles. The equation to the parabola, referred to these tangents as rectangular co-ordinates, is

$$x^2 - 2xy + y^2 - 200\sqrt{2}\,(x + y) + 20000 = 0.$$

and gives on solution the following corresponding values of x and y:—

$x = 100\sqrt{2} - 3$ feet	$y = 0{\cdot}1932$ inch
$100\sqrt{2} - 2$,,	$0{\cdot}0856$,,
$100\sqrt{2} - 1$,,	$0{\cdot}0216$,,
$100\sqrt{2}$	$0{\cdot}0000$,,
$100\sqrt{2} + 1$,,	$0{\cdot}0204$,,
$100\sqrt{2} + 2$,,	$0{\cdot}0830$,,
$100\sqrt{2} + 3$,,	$0{\cdot}1884$,,

Next compute the subtenses of the radii of the circles in which the parabola will revolve round the axis in becoming a paraboloid of revolution at the points -2, -1, 0, $+1$, $+2$, or take,

$$98^{\text{f}}{\cdot}5158,\quad 99^{\text{f}}{\cdot}2929,\quad 100^{\text{f}},\quad 100^{\text{f}}{\cdot}7071,\quad 101^{\text{f}}{\cdot}4142$$

and we get

Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
		0·0025	0·0024	0·0023		
	0·0006	0·0006	0·0006	0·0006	0·0006	
0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
	0·0006	0·0006	0·0006	0·0006	0·0006	
		0·0025	0·0024	0·0023		

If now we add together these numbers, we shall have a measure of the curvature of each point of our mirror, expressed as subtenses from the plane at the tangent at point A or B, at 1 foot apart every way,—namely,

Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
		0·0241	0·0024	0·0227		
	0·0862	0·0222	0·0006	0·0210	0·0836	
0·1932	0·0856	0·0216	0·0000	0·0204	0·0830	0·1834
	0·0862	0·0222	0·0006	0·0210	0·0836	
		0·0241	0·0024	0·0227		

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It remains to be seen whether any artist can construct an ellipse of 6 feet by 4, on such a curvature, parabolic in the direction of the major axis and circular in the direction of the minor axis. The curve is a very flat one. The ratio of aperture to focal height will be $\frac{4}{100}$ or $\frac{1}{25}$. A list of these ratios may be seen in Professor Powell's paper in the *Monthly Notice* of March 13, 1857, taking into account the errata mentioned at page 222, and it will be seen that for the Northumberland Equatoreal at Cambridge $\frac{A}{F} = \frac{1}{20{\cdot}3}$. My proportion is long, but not extraordinary. Having defined the mirrors I would get, I now proceed to show how I would place them, and refer to figs. 2 and 3, where it will be seen that I propose to place them back to back, at an angle of 90°, with their two foci turned outwards at a distance apart of 205 feet, or thereabouts. Observers are supposed placed at A and B, looking through two eyepieces *floating*, as I have before said. Now turn to fig. 4, and notice the collimator in the centre, which consists of two object-glasses, 8 inches in diameter, viewing each other. These must be of 103 feet focal length each, or thereabouts; and their object is, by turning the instrument round, as in fig. 4, to let them be seen through at the same time, and to inspect the line of level till it is placed perfectly and zero. The eye-pieces are then to be clamped in level. By turning the instrument round to the polar star, observe, with A eye-piece on A mirror, and B eye-piece on B mirror, a complete set of passages of the polar star; and likewise, with A eye-piece on B mirror, and B eye-piece on A mirror, the same, and you have the values of wires known. Next, with A eye-piece on A mirror, and B eye-piece on B, take a transit of one wire, then turn A to B and B to A, and take another. This comparison gives you the collimation error doubled. Then, again, compare with a south star and you determine the azimuth.

Of course I do not mean this simply. The observer would be more likely to take 4 wires in one position and 3 in the other, alternately. To move the mirror in azimuth and altitude, and read off the microscopes, I suppose two other observers are required, thus requiring four persons at a shift. I reckon three hours at a shift, and four observers at each shift. Thus for three shifts I should provide twelve men, and be ready at all times, day and night, when the sky is clear. Fig. 6 gives the position of the instrument as seen for observation, the spaces painted blue being the mirror of one side, and those painted pink the altitude circle with its pair of micrometers. There are two altitude circles and two pairs of micrometers, as shown in figure 5. The azimuth circle is seen below, painted yellow. There is also a rough azimuth circle for the purpose of setting, which might be graduated by comparison with the fixed circle read by six microscopes.

Of course, it will be said, "What is the use of proposing schemes which can never be accomplished?" To this supposed question I might answer, "What is the use of sitting still and

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never imagining anything beyond what is put before you?" But I will endeavour to meet the objection by pointing out that whatever you do, it is essential to bear in mind that as soon as you pass the limit of size of a revolving object-glass, as is pretty nearly done already (for I reckon that no one will propose again to mount a larger object-glass than 12 inches in diameter, as is done in the transit-circle at Greenwich, for example), you come upon the question, "What is the simplest form of instrument with a fixed object-glass?" And I say, till I am corrected, that at the bottom of all lies the fact that you must have a mirror capable of being placed at all angles to the horizon. It depends on whether you prefer metal or glass. For glass you have three persons only to apply to,—Mr. Chance of Birmingham, M. Feil of Paris, and a Belgian manufacturer. The cost, which I put out of account, would be enormous. Taking my prism of 6 inches in the side, which cost £60, and reckoning the cost at the cube of the dimensions, a pair of prisms of guaranteed quality would come to £61,440, besides the cost of a pair of object-glasses.* M. Feil's price would be lower than this, if he would undertake the size at all. But as this is practicable, let us consider it, only bearing in mind that you have six surfaces to contend with instead of one in the mirror. The construction will be as follows:—First, I erect a steel axis, 18 feet high by 2 feet in diameter, with a head of 8 feet diameter by 1 foot 4 inches deep, on to which I attach a platform of boiler-plate work, braced wherever necessary, of the size of 20 feet by 20 feet, and 2 feet deep, attached by 12 enormous screws to the head of the axis. This, I imagine, will carry anything put upon it, and that an observer standing on it would not affect it the slightest. Above this come two hydraulic presses, shown in the centre, carrying the counterpoises, each of four wheels, 4 feet in diameter, the position and action of which a comparison of the diagrams will show. Then the Y's, which I no longer make in the form of Y or V, but I will say the guides, each adjustable, and reckoned to bear strains of 20 lbs. each, the counterpoises taking the main actual strains. Then I suppose constructed a cylinder, of boiler-plating, braced or solid as may be thought best, of the external dimensions of 17 feet in length and 6 feet 8 inches in diameter, internal diameter 4 feet, in which I suppose the prisms and the object-glasses placed as drawn.

These dimensions, though necessary to be given, are, I am aware, only a poulterer's description of a phœnix, as Sheridan once said, and it may be well to point out, that at each end of the 17-feet tube I place a revolving circle in altitude, of the unavoidable size of 9 feet diameter, and in the centre two other circles, one for clamping and the other for setting by with a

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* This is incorrect. The contract was for 7 inches, of which one was to be ground away. In the same way take 49 inches as the contract, and you have £120 × 7 × 7 × 7 = £41,160.

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tangent screw (not drawn). The azimuth-circle I make of the same size, 9 feet diameter, read by six microscopes. There is no advantage gained in so large a circle, but rather the contrary. I hold that a circle of 30 inches, or 3 feet without spokes read by powerful microscopes, 6 feet in length, is capable of doing better work than one of 9 feet, subject to the same variations of temperature. I have drawn plans for four microscopes in altitude, two to each circle, but they may be replaced by six to each circle if required, and no objection is made to lengthening the platform.

It will be asked of what I propose to make the pivots,—I reply, of steel, shrunk on to the boiler-tube, and then turned down on dead centres. They will be 7 feet in diameter. The screws of the altitude circle appear to be turned the same way, but they work in opposite directions. My own are so placed.

The drawings are given to the scale of $\frac{1}{100}$ for the parabola and figs. 2 and 3, and $\frac{1}{16}$ for all the rest, in the originals; but in the lithographs are reduced one sixth again, so that figs. 1, 2, and 3 are in the proportion of $\frac{1}{600}$, and the others $\frac{1}{96}$.

It may be pointed out that by supposing a hollowed tube of 17 feet length, the mirrors of the first design can be supported throughout, resting on the back.

I have only to add, that I recommend that the webs of the micrometers be of parallel lines, of the same strength as the division which is seen between them; and that guide-lines should be engraved on the circles to indicate that the point viewed is the centre, and not any other part of the division. My circles at Churt are so divided.

On Mr. Carrington's Note of the Rate of a Clock going in a partial Vacuum. By Rev. T. R. Robinson, D.D.

I have read with much interest Mr. Carrington's account of the rate of his clock in a partial vacuum, given in the last Number of the *Monthly Notices;* for, although the barometric compensation which I applied to the Armagh transit-clock is completely successful, yet the adjustment of it requires too much time by calculation for that method to be generally adopted; while there is no great difficulty in establishing a clock in a rarefied medium of invariable density.

Mr. Carrington's chief impediment seems to have been the fracture of the plate-glass enclosing the front of his clock-case. This would not have occurred if he had constructed the case on the plan invented by Sir Edward Sabine, and modified by the late Mr. Francis Baily, in their researches on the reduction of a pendulum's rate to a vacuum (*Phil. Trans.* 1829 and 1832.) In their apparatus large flat surfaces of glass are avoided; and the pressure is sustained by convex ones, on the principle of the arch. Many years ago the late Sir James South made such an